UNIVERSITÄT DUISBURG ESSEN

Open-Minded

An integrated approach to model redispatch and assess potential benefits from Market Splitting in Germany

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Enerday in Dresden, 19/04/2013

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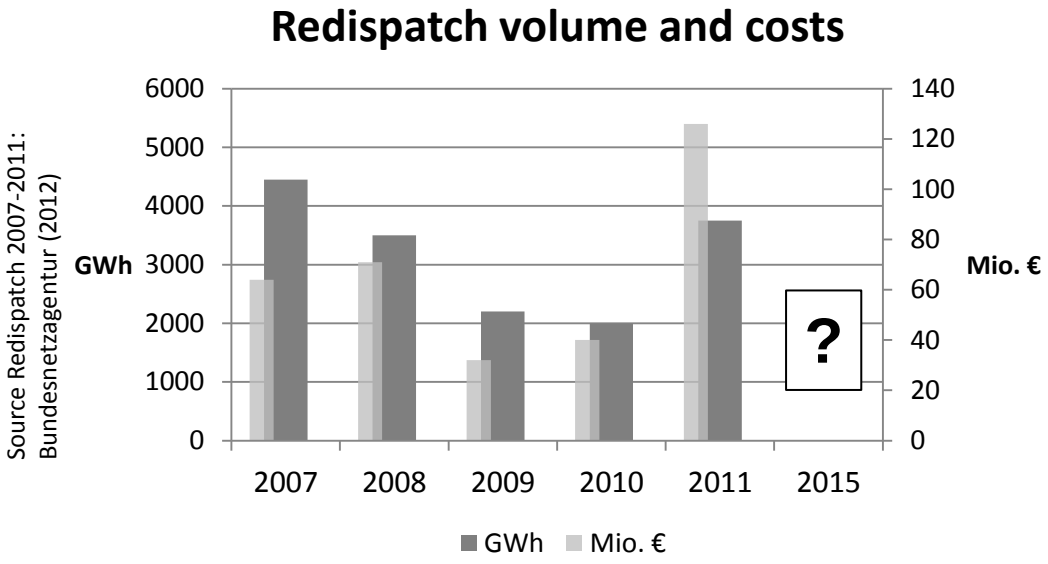
Overview

Motivation

- Increasing RES-feed-in, grid extension not keeping pace with RES, accelerated nuclear phase-out and increasing international trading activities are challenging the transmission grids



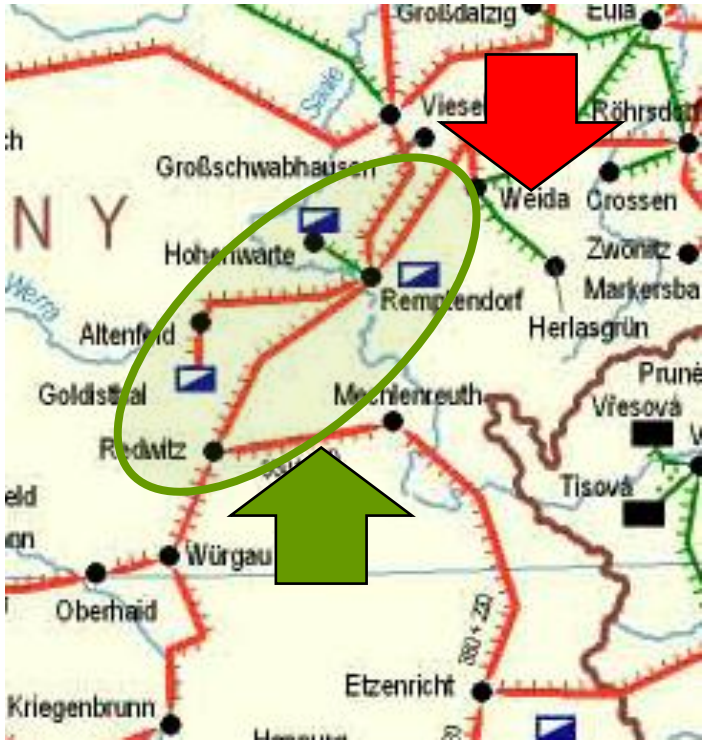
Motivation

- Increasing RES-feed-in, grid extension not keeping pace with RES, accelerated nuclear phase-out and increasing international trading activities are challenging the transmission grids
- **Increasing difficulties for TSOs in daily grid operation**
  - Congestion management and redispatch
  - Stability and security concerns
- First-best answer for congestion management according to textbook economic theory: Market Splitting through Nodal Pricing
  - ➢ Timely implementation is unrealistic, German-/ European-wide TSO needed
- **Alternative: Market Splitting through Zonal Pricing (?)**
  - → Implications for congestion and redispatch?
  - → Implications for Security of Supply (SoS)?

1. Introduction

Congestion Managament in Germany: Day-ahead market „copperplate“ + Redispatch

Redispatch = remove transmission congestion by changing generator output levels to reduce congestion and keep up system security



Source: ENTSOE (2012)

- We assume: 500 MW congestion between Remptendorf and Redwitz
- Redispatch measure:
  - Down-regulating of power plant in front of the bottleneck **(Negative redispatch)**
    - How much MW have to be down-regulated depends on the effectiveness of the power plant on the specific congested line
  - Up-regulating of power plant behind the bottleneck **(Positive redispatch)**
    - According to energy amount that has be down-regulated „in front of the“ bottleneck

Research issues

[1.] Redispatch

- Development of an adequate model approach for redispatch
- Redispatch development in future? Drivers?

[2.] Market Splitting

- Impacts of market splitting on redispatch amount?
- Specific design of bidding zones?
- How much zonal (transfer) capacity is given to the Day-ahead market?
- How much redispatch is still necessary – despite of the introduction of market splitting?

Overview

2. Model Framework

Modelling Redispatch: Conflicting requirements → Usage of 2 model variants

- **Detailed** modelling of **power plant dispatch**, electricity flows between regions and **redispatch**
  → Need for unit-wise (MIP) modelling
- Impact of **varying production of RES** and conventional power plants on **German imports and exports** and therefore also on **redispatch**
  → Need for modelling of the whole ENTSO-E grid

→ European-wide MIP-model computationally too demanding
  – Huge model size: MIP-modelling of EACH European power plant

→ **Solution:** ***LP-Model Europe*** → ***MIP-Model Germany***

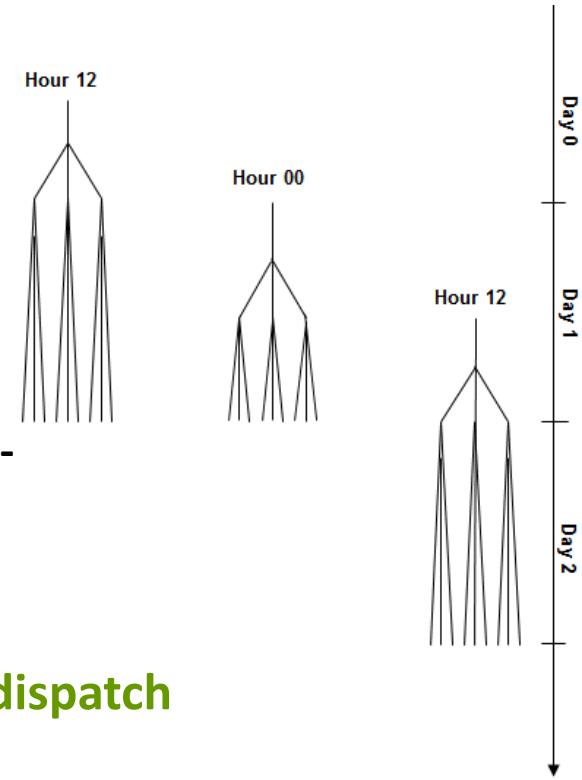
- **Imports and exports**
- **Electricity produced in subordinated grids**

Basic Characteristics of the Dispatch Model: Joint Market Model (I)

- Objective function minimizes variable generation costs

- Detailed hourly optimisation of power plant dispatch for 8760 hours
  - Linear respectiveley mixed-integer optimisation
  - Rolling planning approach
  - Planning horizon up to 36 h with hourly optimisation

- Consideration of arrival of new information („wait-and-see“ decision-making structure),
  - 1rd step: Optimisation of power plant dispatch from a **day-ahead** perspective
  - 2nd step : Readjustment of power plant dispatch based on new **intraday** information (e.g. modified wind production, grid restrictions) **= redispatch**



Basic Characteristics of the Dispatch Model: Joint Market Model (II)

- Detailed formulation of technical restrictions
  - start up-costs, part-load efficiency losses, CHP plants, pumped storages, reserves, …
- Load flow approximation:
  - European 50-node-model: thereby Germany in 21 nodes
  - Germany: PTDF and regional NTCs, both from German load flow model (600^{+} buses, transmission grid)
  - Outside Germany: NTCs from ENTSO-E, ex-post PTDF
- Development within the EU-projects WILMAR and SUPWIND, used in several studies e.g. EWIS or TSO studies *(redispatch, evaluation of concrete grid extension projects, market design issues)*, used from several research institutes *(Universities of Essen/ Stuttgart/ Denmark/ Dublin)* and also in industry
  - ➢ See for a more detailed model description including equations: Weber et al (2009), Meibom et al (2009) and Tuohy et al (2009)

2. Model Framework

Model Coupling: how to consider Europe?

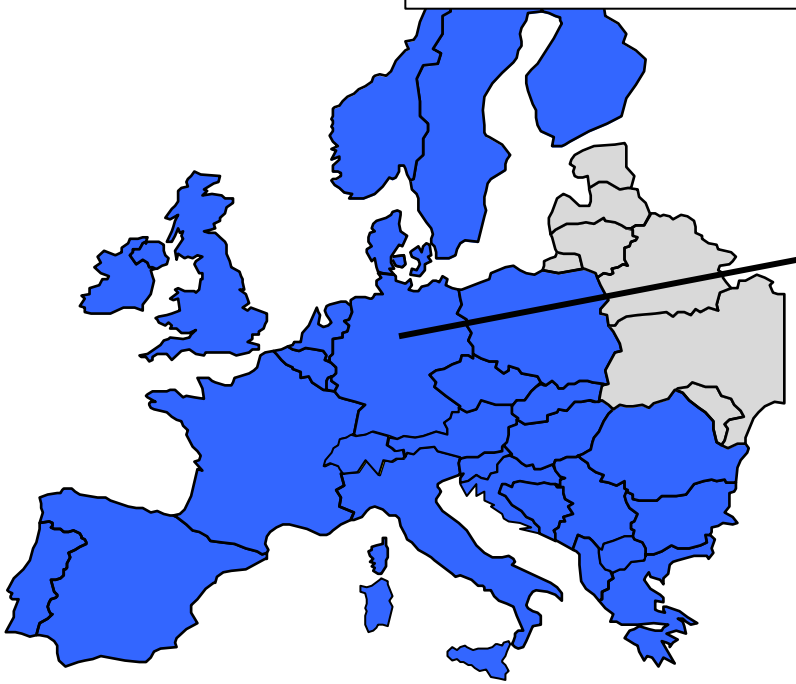
LP-Model Europe

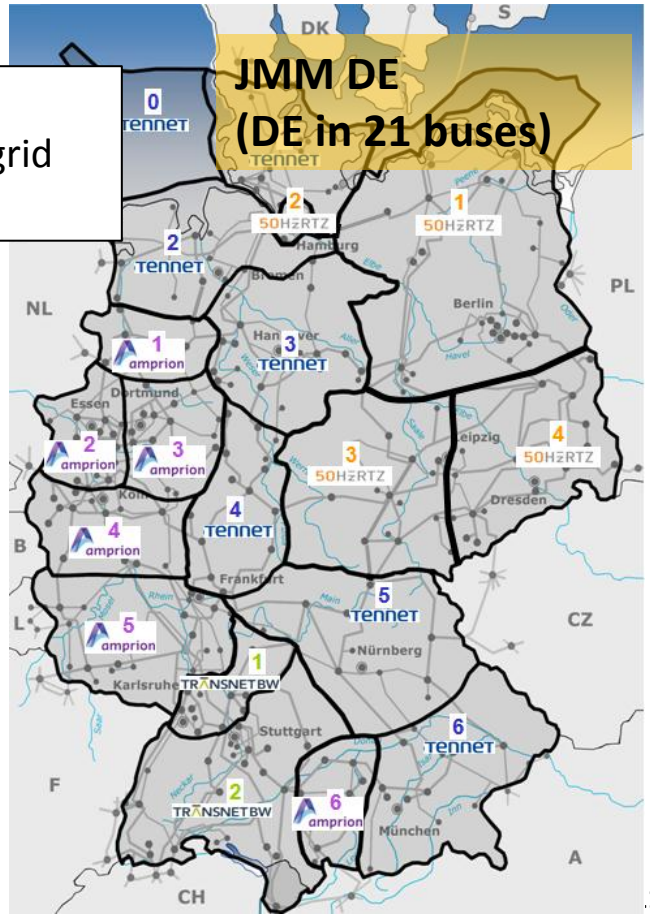
→ **Coupling of models**

MIP-Model Germany

JMM Europe (DE in 21 buses)

- Imports and Exports
- Electricity produced in subordinated grid (for determination of vertical load)





Source regional model: TSO websites

2. Model Framework

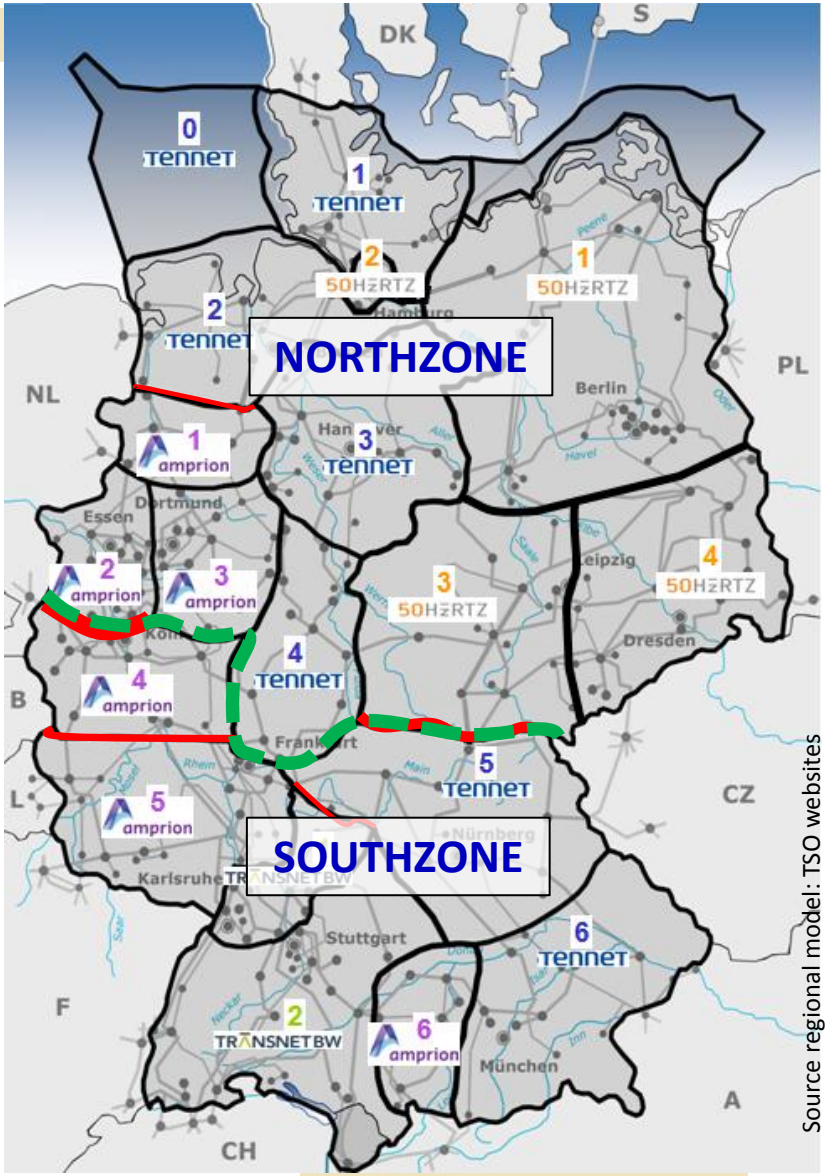
1st Challenge: Definition of market zones

Model results 2015:

- Main bottlenecks :
  - **Amp2-Amp4** *(new coal-fired power plants, partly compensation by decomissioning of old lignite-fired units)*
  - **Te5-50Hz3** *(already now most congested line „Thüringer Waldleitung“, wind-driven)*

(Effective) congestion management requires:

- Zonal border should run along the main bottlenecks to manage congestion already day-ahead



Source regional model: TSO websites

2. Model Framework

2nd Challenge: Definition of zonal day-ahead capacity

- Trade-Off: System security vs. market liquidity
- The lower the zonal transfer capacity given to the day-ahead market
  - The higher is the system security
  - The lower is the market liquidity (less trading between market zones possible)

→ **Comprehensible and transparent approach:**

→ **NTC calculation between market zones according to Entso-E**

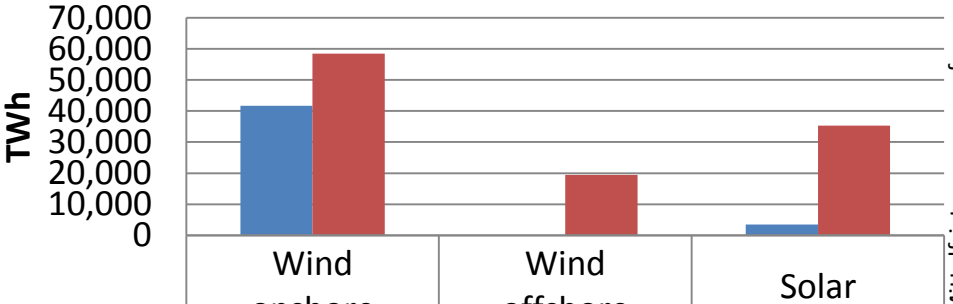
1. Determination of base case exchange between market zones [BCE]
2. Determination of maximal additional transmission capacity between zones by increasing exchange (until constraints are binding) [delta_Emax]
3. Calculation of Transmission Reliability Margin [TRM]
4. NTC = BCE + delta_Emax - TRM

Overview

1. Introduction
2. Model Framework
3. Case study Germany: Redispatch and Impacts of Market Splitting
4. Findings and Conclusion

Key Assumptions 2015

- Load: 2008 (Profile and total amount)
- Fuel and CO_2-Prices: Future prices for 2015
- Power plants 2015: EWL-Datenbank & Bundesnetzagentur (2011)
- Grid 2015: "Realistic"
  - Europe: No consideration of NorGer, NordLink, Cobra Cable…
  - Germany: Consideration of Görris-Krümmel, Lauchstädt-Vieselbach, Hamburg/Nord-Dollern and phase shifter Diele
  - → But no full consideration of all Enlag projects
- RES-production:

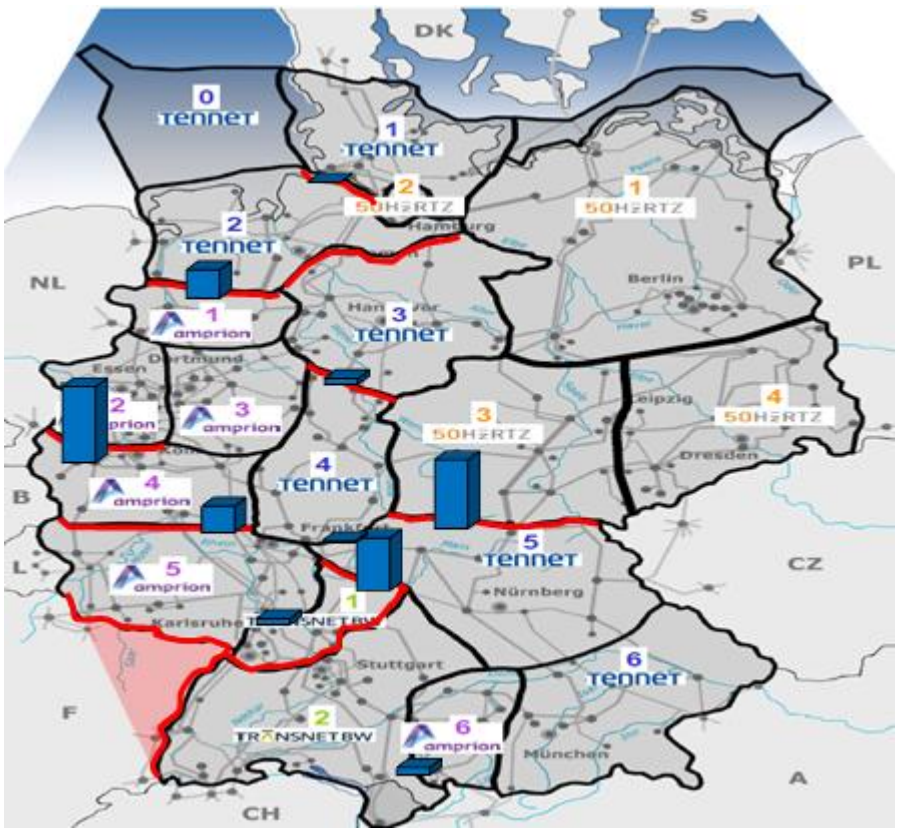


	Wind onshore	Wind offshore	Solar
2008	41,711	0	3,521
2015	58,487	19,452	35,284

Source: EEG-Mittelfristprognosen of German TSOs

Development of Congestion 2015

Congestion amount = amount of energy not transmitted due to congestion



Source regional model: TSO websites

Top 10 constrained regional borders

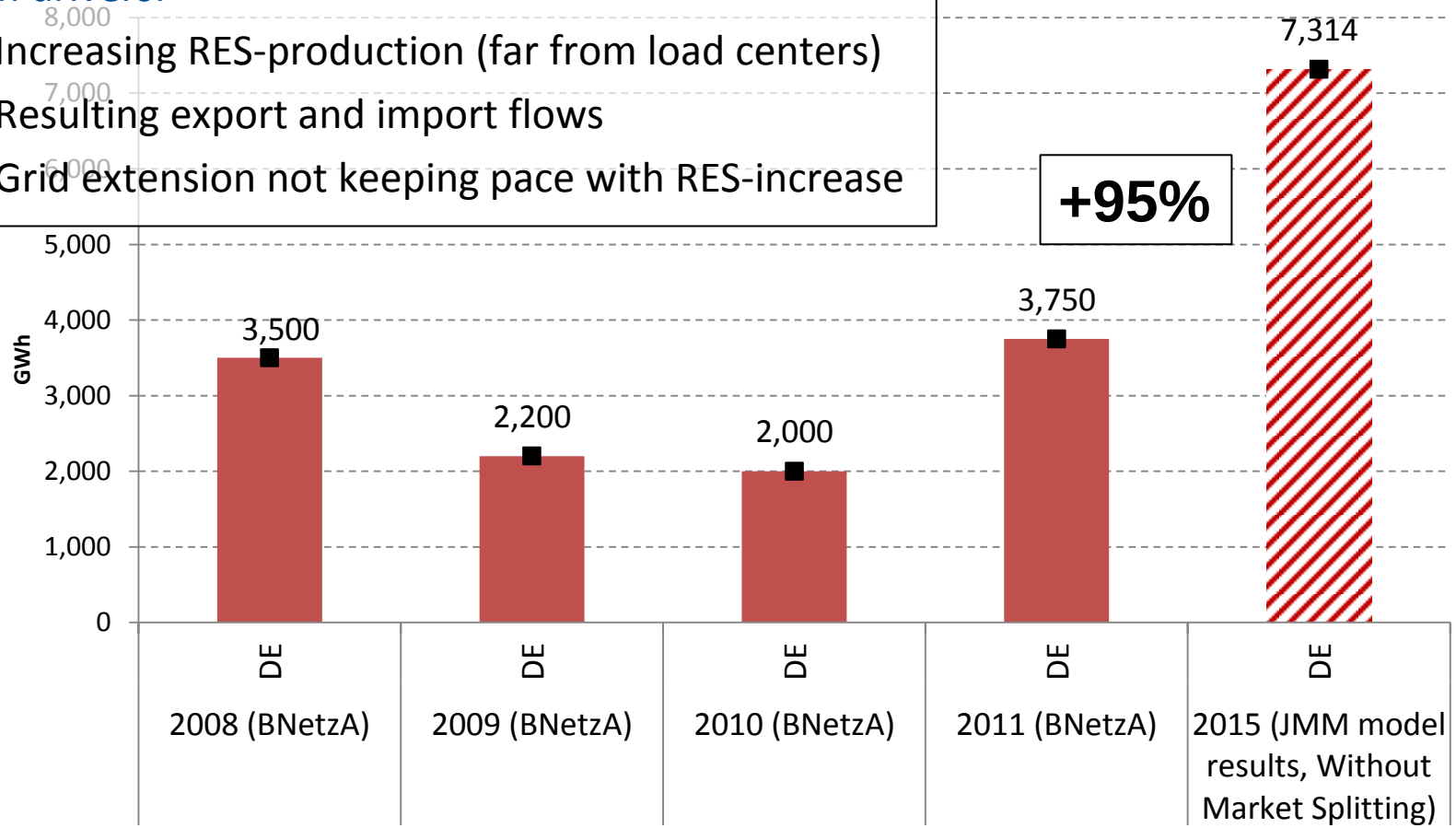
Regional border	Congestion amount (GWh)
AMP2_AMP4	**2,559**
Te5_50Hz3	**2,322**
AMP4_AMP5	887
Te5_TrBW1	**1,754**
Te2_AMP1	955
TrBW2_AMP6	243
Te1_Te2	0
Te3_Te4	199
TrBW1_AMP5	201
Te4_Te5	69

3. Case study Germany - Results

Development of Redispatch until 2015

Main drivers:

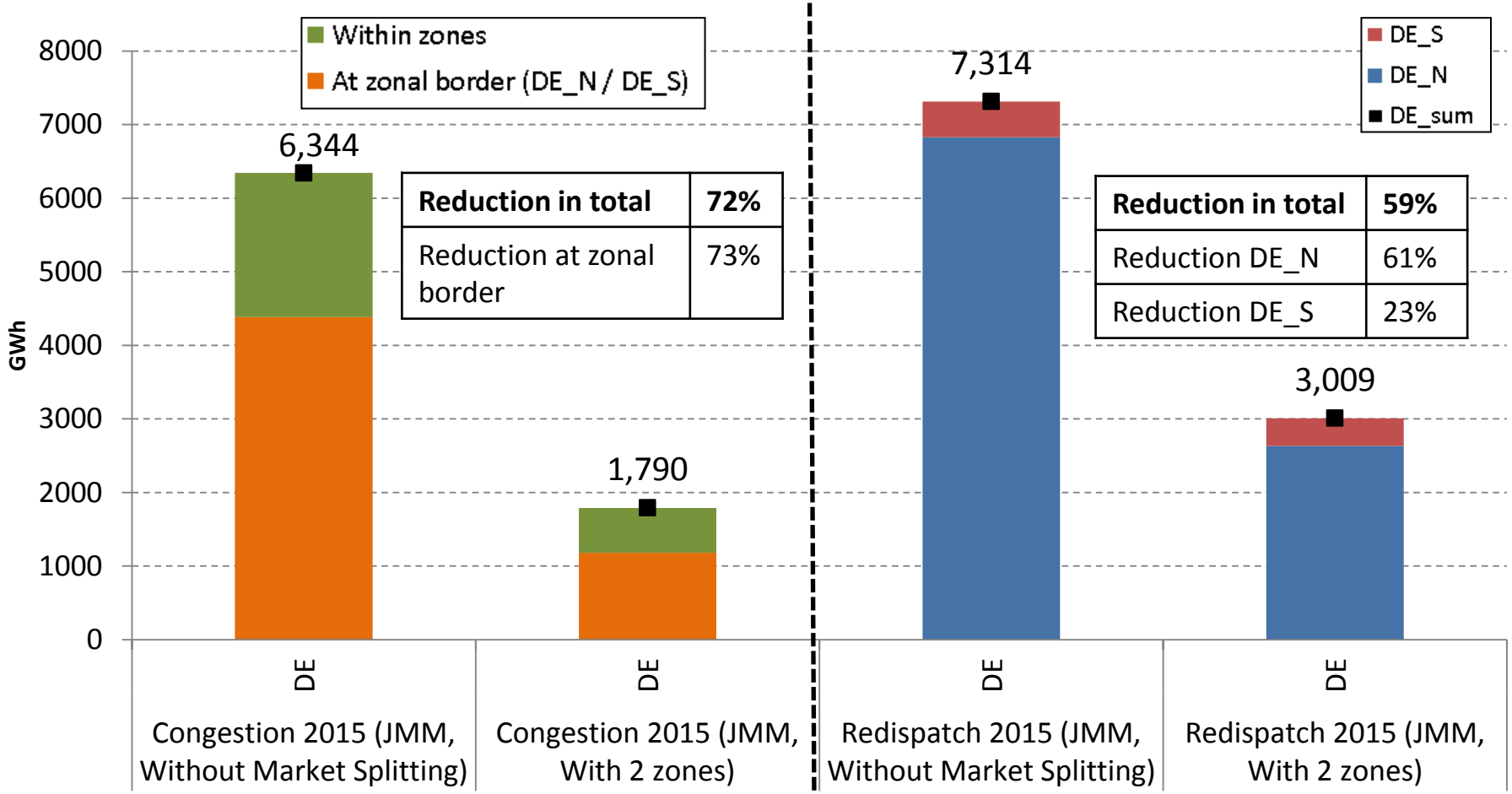
- Increasing RES-production (far from load centers)
- Resulting export and import flows
- Grid extension not keeping pace with RES-increase



Source Redispatch 2008-2011: Bundesnetzagentur (2012)

3. Case study Germany - Results

Impacts of MSpl on Congestion and (negative) Redispatch 2015

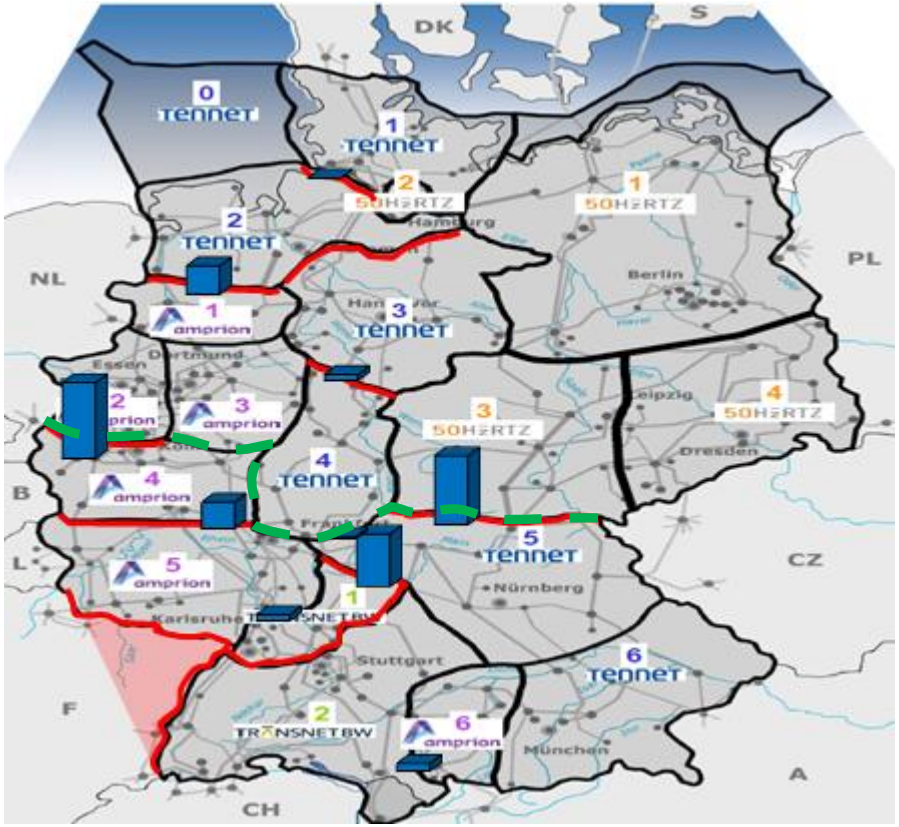


Reduction in total	72%
Reduction at zonal border	73%

Reduction in total	59%
Reduction DE_N	61%
Reduction DE_S	23%

Congestion 2015 – without MSpl

Congestion amount = amount of energy not transmitted due to congestion



Source regional model: TSO websites

Top 10 constrained regional borders

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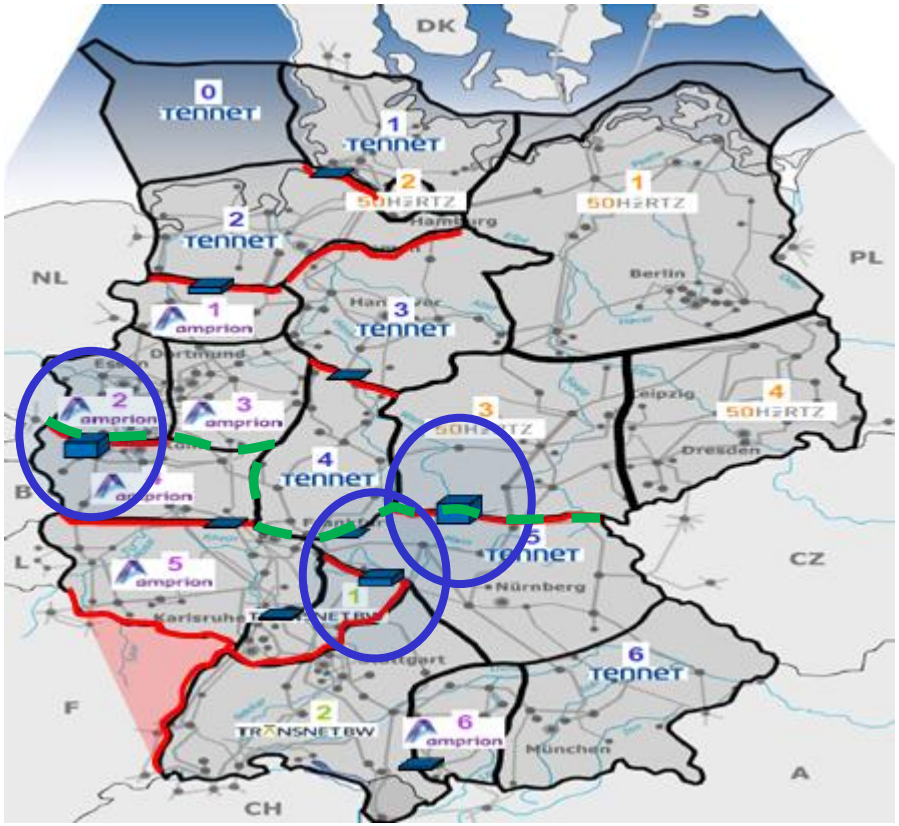
Congestion 2015 – with MSpl (2 zones)

Congestion amount = amount of energy not transmitted due to congestion



Source regional model: TSO websites

Top 10 constrained regional borders

Regional border	Congestion amount (GWh)
AMP2_AMP4	**509**
Te5_50Hz3	**668**
AMP4_AMP5	10
Te5_TrBW1	**241**
Te2_AMP1	201
TrBW2_AMP6	89
Te1_Te2	0
Te3_Te4	10
TrBW1_AMP5	53
Te4_Te5	0

3. Case study Germany - Results

(Negative) Redispatch 2015 – without MSpl

(Negative) redispatch quantity* = redispatched amount of energy due to congestion

Source regional model: TSO websites

Top 10 constrained regions

Region	Redispatch quantity (GWh)
AMP2	**3,262**
50Hz3	**1,688**
50Hz4	**936**
Te2	**459**
Te3	224
Te5	119
Te1	114
TrBW1	103
50Hz2	99
Te6	82

*not equal to congestion amount due to system stability requiremens and spatial deviation of congestion and generating facilities

3. Case study Germany - Results

(Negative) Redispatch 2015 – with MSpl (2 zones)

(Negative) redispatch quantity* = redispatched amount of energy due to congestion

Source regional model: TSO websites

Top 10 constrained regions

Region	Redispatch quantity (GWh)
AMP2	**714**
50Hz3	**944**
50Hz4	**502**
Te2	**115**
Te3	174
Te5	80
Te1	103
TrBW1	100
50Hz2	66
Te6	90

*not equal to congestion amount due to system stability requiremens and spatial deviation of congestion and generating facilities

Overview

1. Introduction/ Motivation/ Congestion Management in Germany
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Concerning Redispatch

- Increase in redispatch quantitites by 95% until 2015 (compared to 2011)
- Main drivers:
  - Increasing RES-production (far away from load centers)
  - Resulting export and import flows
  - Grid extension not keeping pace with RES-increase (delays?)
  - *Nuclear phase-out (Atommoratorium)*
- Main bottlenecks: Thüringer Waldleitung (Te5-50Hz3) and Amp2-Amp4
  - ➢ Assumption of grid extension Hamburg-Nord/Dollern decreases Bottleneck Te1-Te2
  - ➢ Huge loop flows from North of Germany over CZ and PL to South of Germany

Concerning Market Splitting

- MSpl can reduce redispatch quantities very substantially
  - Complete avoidance of redispatch is yet not feasible (plant outages, forecast errors…)
- Beneficial effects of MSpl for the SoS in DE depend strongly on a ‚good design‘, in particular:

(1) Appropriate design of day-ahead market zones
  - Zonal borders should run along the main bottlenecks
  - Changing flow patterns will require regular checks and adaptations

(2) Appropriate determination of zonal transfer capacity

Concerning Market Splitting

- MSpl can have a very significant reducing effect on redispatch
  - ➢ Complete avoidance of redispatch is yet not feasible (plant outages, forecast errors…)
- Beneficial effects of MSpl for the SoS in DE depend strongly on a ‚well design‘, in particular:

(1) Appropriate design of day-ahead market zones:

(2) Appropriate determination of zonal transfer capacity: **Too high ?**

- ➢ Tradeoff: Market liquidity vs. efficient congestion management **Too low?**

→ Leads to reduction of liquidity

→ Leads to reduction of efficiency

Concerning Market Splitting

- MSpl can have a very significant reducing effect on redispatch
  - Complete avoidance of redispatch is yet not feasible (plant outages, forecast errors…)
- Beneficial effects of MSpl for the SoS in DE depend strongly on a ‚well design‘:

(1) Appropriate design of day-ahead market zones:

(2) Appropriate determination of zonal transfer capacity:

- MSpl cannot be expected to be the ‚one and only‘ solution.
  - Need for differentiated assessment between market splitting and grid extension to mitigate SoS risks
  - Also TSO measures like flow-controlling devices have to be taken into account
- MSpl can be an adequate way to manage congestion in times of „grid delays“ and as alternative to grid extension within less congested areas

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Thank you for your attention!

Any questions, remarks or comments?

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Literature (I)

- Bundesnetzagentur (2011): **Kraftwerksliste der Bundesnetzagentur zum erwarteten Zu- und Rückbau 4.Quartal 2011 bis 31.12.2014**, Stand 28.09.2011
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Literature (II)

- TSO websites (www.amprion.net, www.tennettso.de, www.transnetbw.de, www.50hertz.com)
- Tuohy, A., Meibom, P., Denny, E., O'Malley, M.: **Unit Commitment for Systems With Significant Wind Penetration**. In: IEEE Transactions on Power Systems (2009) 24 Nr. 2, S. 592-601.
- Weber, C.; Meibom, P.; Barth, R.; Brand, H. (2009): **WILMAR - a stochastic programming tool to analyse the large scale integration of Wind Energy**. In: Kallrath, J.; Pandalos, P.; Rebennack, S.; Scheidt, M. (Hrsg.): Optimization in the Energy Industry. Springer, New York 2009, S. 437 - 460.

Annex

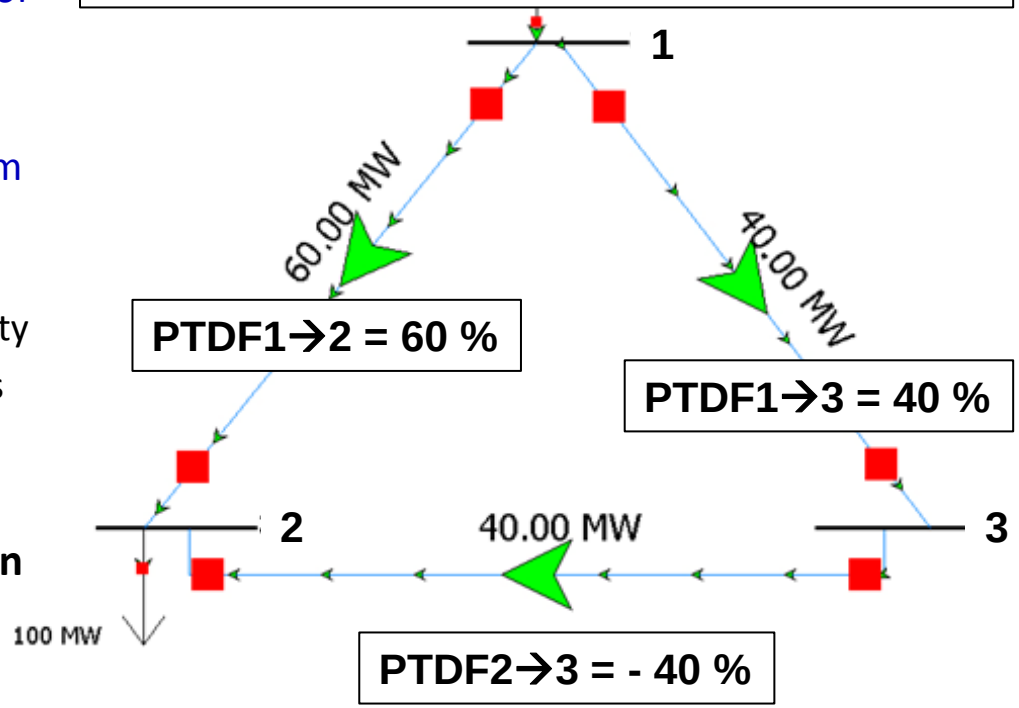
Conventional power plants 2015

- Consideration of commisioning and decommisioning of power plants as far as known/expected, including:
- Commisioning Germany:
  - Wilhelmshaven (Coal, ca. 750 MW, Te2)
  - Moorburg 1 + 2 (Coal, 2 x 755 MW, 50Hz2)
  - Grevenbroich-Neurath BoA 1 + 2 (Lignite, 2 x 1,050 MW, AMP2)
  - Datteln 4 (Coal, ca. 1,000 MW, AMP2)
  - Hamm 1 + 2 (Coal, 2 x ca. 750 MW, AMP3)
  - …
- Decommisioning Germany:
  - Partly Frimmersdorf (Lignite, ca. 1,200 MW, AMP2)
  - Partly Niederaussem (Lignite, ca. 550 MW, AMP2)
  - …
- Based on power plant list as published by Bundesnetzagentur

Load Flow Approximation by PTDF

- **Power Transfer Distribution Factor (PTDF):**
  - → Relative change in power flow on a particular line due to a change in injection and corresponding withdrawal at a pair of busses
- **Net Transfer Capacity (NTC):**
  - → Maximum commercial exchange program between two interconnected market zones
    - without compromising system security
    - and taking into account uncertainties on future network condiditons
- **BCE: Base Case Exchange**
- **ΔE: Maximum additional exchange between two buses**
- **TRM: Transmission Reliability Margin**

NTC1→2
= BCE + ΔE – TRM
= 100 MW + (100 MW – 60 MW) / 60 % – TRM
= 166,67 MW – TRM



Load Flow Model

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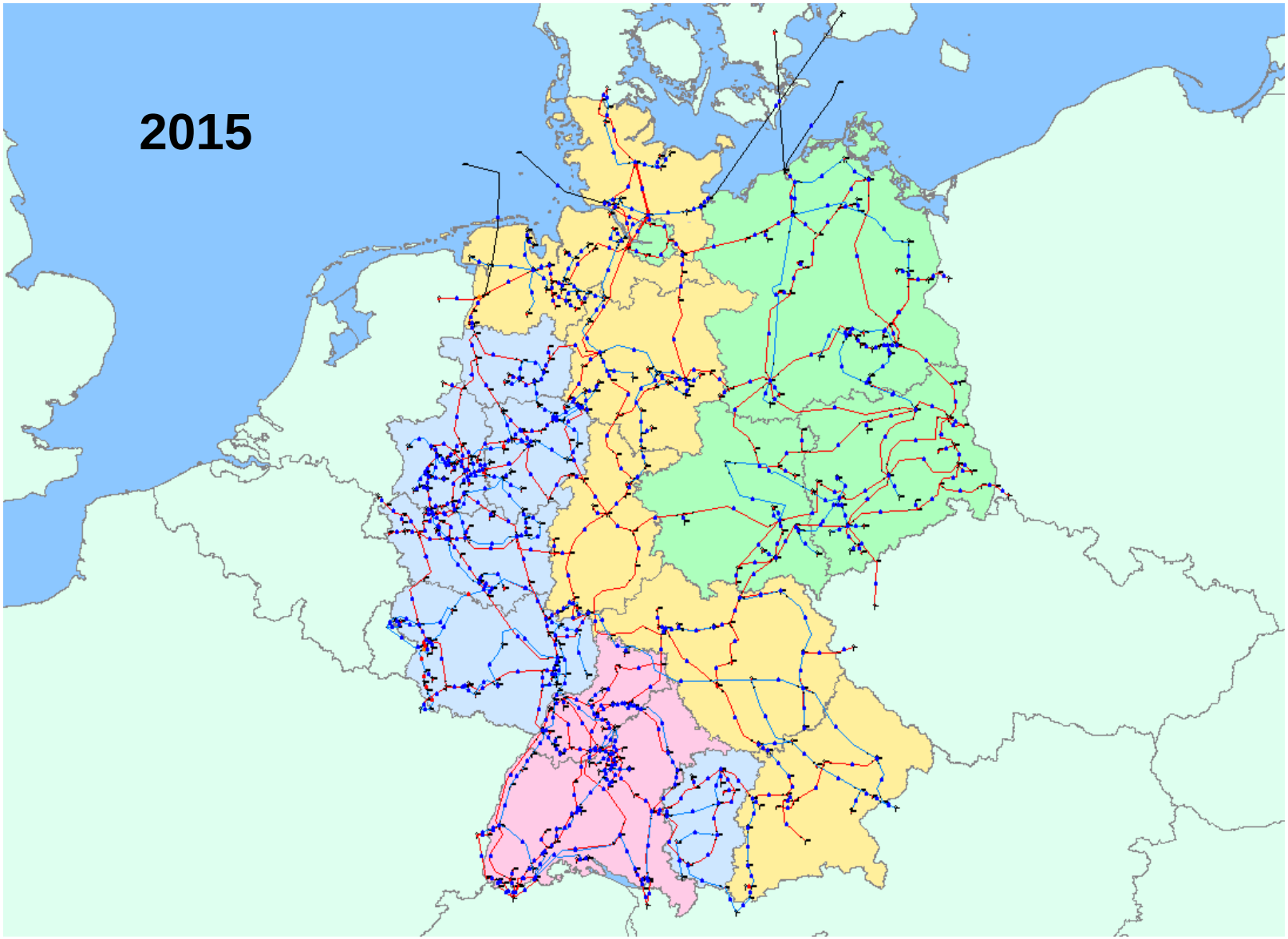

Load Flow Model

Brief description

- Focus on German transmission grid: 220 kV and 380 kV
- 601 buses (454 regular and 147 auxiliary buses)
- Including
  - all generators with an installed capacity greater than 100 MW
  - offshore and onshore wind generation
  - locational residual load levels (load minus photovoltaic feed-in)
- Surrounding countries are represented by country nodes
- Dispatch per unit and the load flows are obtained by running a DC Security Constrained Optimal Power Flow (SCOPF) in PowerWorld Simulator

Impacts of MSpl on (mean) DA prices in Germany

	Without Market Splitting	2 Zones
Hours with Market Splitting	*(unique price)*	2.736 hours
(mean) Price in DE-North	47,58 €/MWh	46,48 €/MWh
(mean) Price in DE-South		48,78 €/MWh
(mean) Price difference	*(unique price)*	-2,31 €/MWh

- In general: The more Market Splitting, the higher is the price difference between market zones
  - Depends on marginal costs of power plants
- In general: The lower the zonal NTC, the more hours with market splitting
  - No linear relationship! Depends on network topology